ABSTRACT

During the past three decades, control room simulators became very important tool used for training of nuclear power plant personnel. There are various international organizations (IAEA, WANO…) that provide exchange of information and experience as well as documents providing guidance on simulator utilization and configuration management.

At Krško NPP, we have started to use our own full scope simulator in April 2000, as a part of major plant modernization project involving replacement of Steam Generators and plant power uprate. In the past, our operators used to be trained on various simulators in United States while there was a long-lasting quest for our own, plant specific simulator. The simulator project, consisting of preparation phase, simulator design, construction, testing and installation on-site, took almost five years.

Since then Krško NPP full scope simulator was to large extent used to support following two major operations personnel training programs:

- **Initial licensed operator training**: the program used to provide comprehensive training for future main control room operators. Program in total duration of 85 weeks consists of following four phases: Fundamentals, Plant systems and operation, Simulator training and On-the-job training in the Main control room. During this program simulator is mainly used during second and third phase.

- **Licensed operator continuing training**: the program used to provide refresher training for already qualified operators. This training is delivered in two-year cycles, comprised of four training segments per year and including up to 80 hours of simulator training for each operating crew annually. In addition, this program includes training on simulated virtual local panels during non-licensed operators training and running of certain number of scenarios for entire operating crews.

There are other training programs and plant activities where Krško NPP simulator was effectively utilized during this time period: Emergency Preparedness Organization drills, training of other plant or external personnel, development and validation of operating procedures, testing of plant modifications, etc.

Simulator Configuration Management Program and supporting processes were effectively established and organized to ensure that simulator is kept consistent with plant status and to enable quality training of operators. The configuration management process involves screening and implementation of plant modifications that have influence on the main control room operation or simulator response, conduct of regular simulator testing to demonstrate simulator correct response and fulfill international standards requirements, continuous maintenance of simulator, etc.
During the past 10 years Krško NPP full scope simulator was introduced in different plant processes, especially training of operations personnel. There are many indicators demonstrating that the simulator was effectively utilized and maintained which provides a good foundation for the future.

1 INTRODUCTION

Utilization of simulators for NPP operators training has become wide established practice during the last three decades. In the 1970’s, when the first computer-based control room simulators were put in service, the scope and fidelity of plant process models were limited by computer capabilities. At the time of the Three Mile Island (TMI) accident there were few NPP control room simulators in operation in the nuclear industry. The future development and availability of technologies enabled the power plants to install new plant specific simulators, which were effectively used for training of their own operators.

Today, the nuclear industry in common, has gained a lot of experience with simulator utilization, while there are various international organizations (IAEA, WANO…) that provide exchange of information as well as documents providing guidance on effective simulator utilization and configuration management.

Krško NPP has started to prepare foundations for purchasing of plant-specific simulator during early 1990’s. At that time the request for full-scope simulator was not an acceptable option due to many reasons, but the plant has undertaken the project for development and installation of Basic Principles Simulator, that was introduced into training programs to support theoretical training.

2 FULL SCOPE SIMULATOR PROJECT

From the time of Krško NPP construction in late 1970’s, our operators used to be trained in United States at different locations. Initial training programs were in great extent delivered by Westinghouse training centre, while the continuing training during last years was delivered by General Physics. Various different simulators were used during that time while none of the simulators used was similar to our main control room design and plant systems configurations were not the same as ours. This was a serious limitation for quality of simulator training, while the training time was limited, also. During all that time there was a strong long-lasting quest for our own, plant specific simulator, which would bring us many benefits.

Krško NPP full scope simulator project has started in 1995 by regulatory act requesting that simulator must be in place at the beginning of year 2000. At that time it was a part of major plant modernization project involving manufacturing and replacement of Steam Generators, plant power uprate analysis and other modifications.

The first step was to prepare a detailed Technical specification that defined technical and other requirements related to the scope of simulation, project schedule, responsibilities, etc. At that time the simulator industry was analysed to obtain insights into current technologies, capacities and references. The request for bids was sent to five possible suppliers in January 1996. Bids were received and evaluated in accordance with previously prepared procedure in April 1996. During first evaluation, three potential suppliers were selected for the second round, when bids were requested to be revised and when negotiations took place. During the second evaluation the Canadian company CAE Electronics Ltd (today L3 MAPPS) was selected for a contract in February 1997.
The scoping and modeling activities as initial part of the simulator design phase have started in September 1997. Besides the CAE personnel, the project team involved a group of plant personnel, providing valuable inputs from engineering and operations perspective. The simulator has undergone intensive testing, performed in the factory. The final testing was completed in October 1999 after which the simulator was transported to Krško NPP site. On-site testing of simulator with new Steam Generators model and configuration of modified systems was completed in March 2000, when simulator was declared ready for training.

The simulator was initially used for training of Krško NPP personnel in April 2000.

![Figure 1: Simulator during factory testing](image)

3 OPERATIONS TRAINING PROGRAMS

Operations’ training includes training of Licensed operators and Non-licensed (field) operators, the groups that play important role in plant day to day operation. Initial training program is conducted in phases and provides operators with needed knowledge and skills to be able to start to work independently. Continuing training is organized in two-year cycles, providing operators opportunity to refresh knowledge and to review changes. Both, initial and continuing training of licensed operators rely on full scope simulator as most important training tool to gain practical skills in operation of the power plant. Non-licensed operators perform practical training in the classroom that is connected to the full scope simulator through graphical interface. Partially, hands-on training is performed in the technological areas of the plant.

During the past 10 years, the Krško NPP simulator was effectively utilized to provide:
- 6400 hours of licensed operators continuing training,
- 4000 hours of licensed operators initial training,
- 10 Emergency preparedness organization exercises…
3.1 Initial licensed operator training

Initial training of licensed operators with total duration of approximately 2 years is performed in phases as presented in the picture below:

- **Fundamentals phase**: trainees are provided with understanding and knowledge of theoretical fundamentals of nuclear technology (nuclear and reactor physics, thermodynamics, electrical science, chemistry…). During this phase the Basic Principles Simulator is used to provide environment for practical exercises as support for classroom theory lessons. Total duration of this course is 20 weeks.

- **Plant systems and operation phase**: during this phase plant systems design and operation is reviewed during classroom lectures. During this phase, the full-scope simulator is used for practical exercises (demonstrations of systems operation, transients…). The part of this phase is also performed in a form of On-the-job training where trainees start to get practical in-plant experience. The total duration of this training phase is 32 weeks.

- **Simulator training phase**: the major purpose of this important training phase is to provide trainees with understanding of plant procedures (normal, abnormal, emergency…) and with the opportunity to train those procedures in the control room environment – simulator. This phase starts with simple normal operation scenarios, continues with announced transients and finishes with completely unannounced transients. At the end of this phase, a final internal exam is administered. The total duration of this phase is 19 weeks.

![Initial licensed operator training program diagram](image-url)

**Figure 2**: Initial licensed operator training program

- **Reactor operator on-the-job training phase**: this practical on-the-job training is performed in the main control room in parallel with simulator training and
provides trainees the opportunity to gain additional practical experience in the real working environment. The total duration of this phase is 14 weeks.

3.2 Licensed operator continuing training

Continuing training of licensed operators is performed in two-year periodic cycles. Program content is based on a 2-year plan and current training needs. During each year, four weekly segments of continuing training are delivered. Training segments are repeated for six operating crews plus two operations licensed staff groups and for the instructors as part of scenario validation week. During each training week, approximately 15 hours of training is delivered in the classroom, while 20 hours of training are performed on the simulator. On the annual basis, each licensed operator is involved in:
- 80 hours of simulator training,
- 60 hours of classroom training.

Totally, 140 hours of training are delivered per each operating crew annually, while 1120 hours of training are delivered for all 8 groups (640 hours on the simulator).

Each training week is started with simulator as-found evaluation, while the written and practical simulator exams are performed during the last training day. The last annual training segment is also used for annual examinations and license renewal exams.

Continuing training program is always delivered for complete operating shifts, which also includes non-licensed operators. Instructors are experienced former MCR operators.

3.3 Other training programs and activities

Krško NPP Plant specific simulator was during last ten years used also for other training programs and activities:
- Ten annual Emergency preparedness organization exercises were performed with the support of the simulator, based on the scenarios that have also involved the beyond design basis accidents.
- Simulator was regularly used for just-in-time training of operating shifts prior to important plant activities as plant shutdowns or startups, special testing, etc.
Simulator was effectively used as an environment for development and validation of operating procedures.
Simulator was used for testing of modifications before their implementation in the plant (SPIS, PDEH…).
Simulator was used for training of other groups (fuel engineers, SNSA inspectors, Angra NPP operators…).

3.4 Benefits of plant-specific simulator utilization

When comparing today operations training practices with those before year 2000, several improvements must be recognized:

- Structure of operations training programs: training programs were redesigned to include practical simulator training,
- Available training time: available simulator training time has been significantly increased,
- Practical evaluations: evaluations of operator performance are conducted using plant-specific simulator; evaluations were improved from the aspect of realism and applicability,
- Management involvement in training: training quality and ownership were improved, operations management has the opportunity to reinforce expectations and evaluate performance,
- Improvements in operator performance: simulator training supported improvements in individual and crew performance,
- Use of procedures: plant-specific procedures are used without exceptions, simulator is also capable of simulating severe accidents,
- Familiarity with control board layout: achieved faster and better, no need to adapt to different simulator layouts,
- Feedback to plant processes: procedure development and validation, application of operating standards and practices, validation of plant modifications,
- Availability of simulator to support other activities: just-in-time training as prerequisite for special or infrequently performed plant activities, training of other groups…

4 SIMULATOR CONFIGURATION MANAGEMENT PROGRAM

The purpose of this program is to define the roles and responsibilities of various plant organizations in order to maintain effective Krško NPP simulator configuration control according to requirements for the full-scope nuclear power plant control room simulators. Simulator configuration management system assures necessary measures for keeping the simulator in a good condition for use in training of licensed personnel and for conduct of licensing examinations. Implementation of this program demonstrates compliance with the requirements of ANSI/ANS-3.5 standard [1]. Internally, Krško NPP specific approach for simulator configuration management is defined in the applicable Program [2].

Since 2000, there were over 1350 simulator model or equipment changes performed due to various reasons. Usually, simulator discrepancies are identified during simulator training, testing or as part of power plant changes. There were 140 modifications of plant systems and equipment or changes in parameters that were identified as having significant impact on the
Simulator model or control room environment. Plant modifications are carefully screened for simulator impact, while major modifications already include the simulator-specific scope of changes. Usually, simulator changes are performed after the plant modifications, but often also before them. There were several important plant modifications that took place on the simulator first. This enabled intensive validation, testing and procedure development to be performed in the simulator environment. It also enabled timely hands on training and familiarization of operators with new or modified equipment. Examples of such modifications were upgrade of Turbine control and monitoring system (PDEH), upgrade of Plant process information system (PIS), etc. Due to the nature of reactor operation and changes of reactor core parameters, there were five simulator reactor core models changes.

Simulator testing plays an important role in simulator configuration management, which verifies its correct response. All simulator changes have to be tested prior to final approval, while there is also a set of transient and simulator stability tests that have to be performed in accordance with annual plan to fulfil international standard requirements.

![Simulator modification (PDEH)](image)

**Figure 4: Example of simulator modification (PDEH)**

**CONCLUSION**

NPP Krško experience in the area of plant specific simulator utilization over the past 10 years can be assessed as very positive. The simulator was very effectively introduced in different plant processes, especially training of operations personnel. There are also other training programs and plant activities where simulator plays an important role. Also, there are many indicators demonstrating that the simulator configuration was effectively managed which provides a good foundation for its future use.

**REFERENCES**


[2] TI-01, Simulator configuration control program

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